

**SODIUM-BEARING PYROXENE IN ALH 84001.** Catherine M. Corrigan<sup>1</sup>, Ralph P. Harvey<sup>1</sup> and John Bradley<sup>2</sup>. <sup>1</sup>Department of Geological Sciences, Case Western Reserve University, 112 AW Smith, Cleveland, OH 44106-7216, <sup>2</sup>MVA Inc., 5500 Oakbrook Parkway #200, Norcross, GA 30093.

The variety of secondary minerals found in the martian meteorite ALH84001 provides clues to the environment conditions present during alteration of the host orthopyroxenite. Discoveries of new secondary minerals help clarify the possible alteration scenarios by offering new pieces to the puzzle presented by this rock's history.

During ongoing efforts to catalog alteration assemblages in ALH84001, an Na-bearing pyroxene phase has been discovered [1]. The phase occurs as fillings of small (~1 micron) euhedral cavities (Figure 1). The original occupant of the cavities is thought to have been chromite based on the shape of the negative crystals and the prevalence of minute chromite grains within ALH84001 pyroxene. The cavities lie within host orthopyroxene, typically only a few microns from grain boundaries between the orthopyroxene and carbonate. Based on stoichiometry, the phase is tentatively identified as acmite / aegerine, a Na-bearing pyroxene where (Na, Fe<sup>3+</sup>) replaces (Ca, Mg, Fe<sup>2+</sup>) within the minerals structure [2]. This identification is not conclusive given that only EDS analyses have been performed so far.

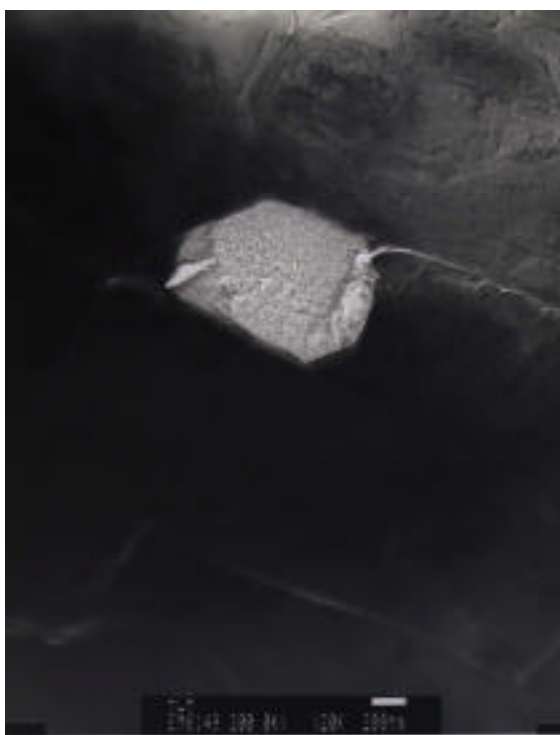


Figure 1: TEM image of euhedral cavity containing acmite phase. Cavity is approximately 1 micron across.

Two end-member scenarios are being considered to bracket possible formation mechanisms for this phase in ALH84001. One possibility is that the phase forms in the same manner as in terrestrial metamorphic settings, where acmite (aegerine) occurs under low- to moderate-grade conditions (greenschist). In this setting, acmite forms in conditions approaching or approximating equilibrium. The alternative scenario is acmite formation under low-temperature, low-pressure conditions, as precipitates or evaporites from a fluid. While such a formation scenario has not been described for terrestrial acmite, it coincides with the conditions proposed by many for the formation of ALH84001 carbonates [3,4,5,6]. Under these conditions, there is no guarantee that acmite is forming in conditions approaching, or even seeking equilibrium, and, thus, accurate determination of formation conditions may be very difficult. However, we would

expect the fluid composition to be oxidizing and saturated in acmite components.

Our initial efforts have been directed toward understanding which of these scenarios is the most plausible given the textures and reaction products that would result

from each, and comparing them to our observations. A critical observation is that acmite (aegerine) is not the only phase represented in these euhedral cavities. When found, acmite has so far been the only phase present in the cavity; however, other cavities contain a mixture of carbonate and magnetite instead of acmite. Acmite has also not been found in ALH84001 in any setting outside the cavities described. This fact would seem to be a point in favor of acmite formation by precipitation, since recrystallization or replacement processes would be expected to take place in all of the cavities to be filled with the same mineral phase (i.e., the original host would be replaced in a consistent manner), or wherever a supply of necessary cations is present.

Given that acmite (aegerine) has not been previously described as a precipitate phase in terrestrial settings, precipitation scenarios must remain speculative. Furthermore, the presence of an oxidizing Na-saturated fluid suggests that other Na-rich precipitates should also be present. The most obvious of these minerals is halite (NaCl), which has not been reported in ALH84001 but has been seen as a minor weathering product in several martian meteorites, and as an enigmatic interstitial phase in Nakhla [7,8,9].

Further insight into possible formation mechanisms for acmite comes from studies of basaltic glasses. Under oxidizing conditions, the surfaces of basaltic glasses become highly enriched in sodium as cations move outward from the interior, while Ca and Mg are carried away by the fluid phase [10]. These Na-cations therefore diffuse readily along grain boundaries. Given that maskelynite glass (feldspathic glass containing Na) occasionally exhibits textures suggesting a reaction relationship with carbonate (where the maskelynite is reacting directly to form carbonate along former grain boundaries), this suggests that grain boundary diffusion from nearby maskelynite can provide a local source for Na cations during acmite formation [11,12]. This process does not necessitate that the fluid be Na-saturated, helping to explaining the absence of halite. It also clearly links acmite formation to carbonate formation.

Future work will fully explore the prevalence of acmite and range of compositions exhibited by the phase. With slightly better data we hope to be able to produce thermodynamic models for the formation of that the truth actually lies somewhere in between the two end-member scenarios suggested.

**References:** [1] Corrigan, C.M., et al. (1999) *GSA Abstracts with Programs*, 31, Abstract #50862. [2] Popp, R.K., and Gilbert, M.C., (1972) *Am. Min.*, 57, 1210-1231. [3] Romanek, C.S., et al. (1994) *Nature*, 37, 655-657. [4] McKay, D.S., et al. (1996) *Science*, 273, 924-930. [5] Valley, J.W., et al. (1997) *Science*, 275, 1633-1638. [6] McSween, H.Y. and Harvey, R.P., (1999) *Planetary Petrology and Geochemistry*, Bellwether Publishing, Columbia MD 252-261. [7] Bridges, J.C., and Grady, M.M., (1999) *Meteoritics and Plan. Sci.*, 34, 407-415. [8] Gooding, J.L., (1978) *Icarus* 33, 483-513. [9] Gooding, J.L., (1992) *Icarus* 99, 28-41. [10] Cooper, R.F., et al. (1996) *Geochim. et Cosmochim. Acta*, 60, 17, 3253-3265. [11] Treiman, A.H., (1995) *Meteoritics* 30, 294-302. [12] Kring, D.A., et al. (1998) *Geochim. et Cosmochim. Acta*, 62, 12, 2155-2166.